E&A

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 616
Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

IMP. BUR. ENTOM. 27 MAR. 1918

Washington, D. C. PROFESSIONAL PAPER February 14, 1918

THE CITRUS THRIPS

By

J. R. HORTON, Scientific Assistant

CONTENTS

	Page		Page
Introduction	1	Seasonal History	22
History and Distribution	2	Natural Checks	24
Nature and Extent of Injury	3	Natural Enemies	25
Dissemination	7	Control Experiments	29
Food Plants	8	Bibliography	41
Life History and Habits	10		

WASHINGTON
GOVERNMENT PRINTING OFFICE
1918

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 616

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. PROFESSIONAL PAPER February 14, 1918

THE CITRUS THRIPS.

By J. R. HORTON,

Tropical and Subtropical Fruit Insect Investigations.[1]

CONTENTS.

	Page.		Page.
Introduction	1	Seasonal history	22
History and distribution	2	Natural checks	24
Nature and extent of injury	3	Natural enemies	25
Dissemination	7	Control experiments	29
Food plants	8	Bibliography	41
Life history and habits	10		

INTRODUCTION.

The citrus thrips [*Scirtothrips*[2] (*Euthrips*) *citri* Moul.] has caused more or less injury to oranges, grapefruit, and lemons in California for the last 20 or 25 years. Owing to its minute size the insect remained undiscovered for many years, and its injury to the fruit was attributed to other causes, such as wind whipping, freezing, etc. About the year 1908 the injury became so severe in Tulare County that the old theories began to be doubted and the need of expert investigation was realized. The preliminary examination in behalf of the Bureau of Entomology was made by Dudley Moulton (2)[3] and resulted in a description of the insect and its injury. Subsequently the bureau undertook a thorough investigation of the life history and control of the insect, this project being started at Lindsay, Tulare County, Cal., in 1909. A report of progress by Jones and Horton (5) and a Farmers' Bulletin on the control of the thrips by the writer (15) have appeared since.

[1] Transferred to Cereal and Forage Insect Investigations, October 1, 1917.

[2] Hood (14) places this insect in the genus Scirtothrips on the apparently adequate grounds that the thorax is finely, transversely striate and the abdomen clothed with minute hairlike processes.

[3] See Bibliography, p. 41.

13138°—18—Bull. 616——1

HISTORY AND DISTRIBUTION.

Although the citrus thrips has been recognized so recently as the cause of the scabbing and scarring of citrus fruits in California, there is unmistakable evidence that it is native to the orange-growing sections of that State and Arizona. Its present known distribution lies within the arid portion of the Lower Austral life zone in central and southern California and south-central Arizona. It is most abundant and injurious in those sections of this area where the minimum rainfall occurs and where the average summer temperatures are highest, such, for example, as in the San Joaquin Valley, where a climate favorable to the development of the pest and extensive recent plantings of citrus offer an ideal environment. In southern California it becomes seriously injurious only in certain seasons and only in the local sections about Riverside, Redlands, Highland, and Rialto, injury decreasing as the coast is approached. The natural habitat of the citrus thrips, therefore, appears to be the arid Lower Sonoran life zone of North America. This belief is substantiated further by its occurrence on plants native to this region and distant from citrus trees. The citrus thrips is known to occur in eight counties in California (see fig. 1), viz., Sacramento, Fresno, Tulare, Kern, Los Angeles, San Bernardino, Riverside, and Orange. The infestation is most serious in Tulare, Fresno, Riverside, and San Bernardino Counties. In Kern County the insect is increasing rapidly and with increased plantings of citrus doubtless will become quite as injurious as in Tulare County.

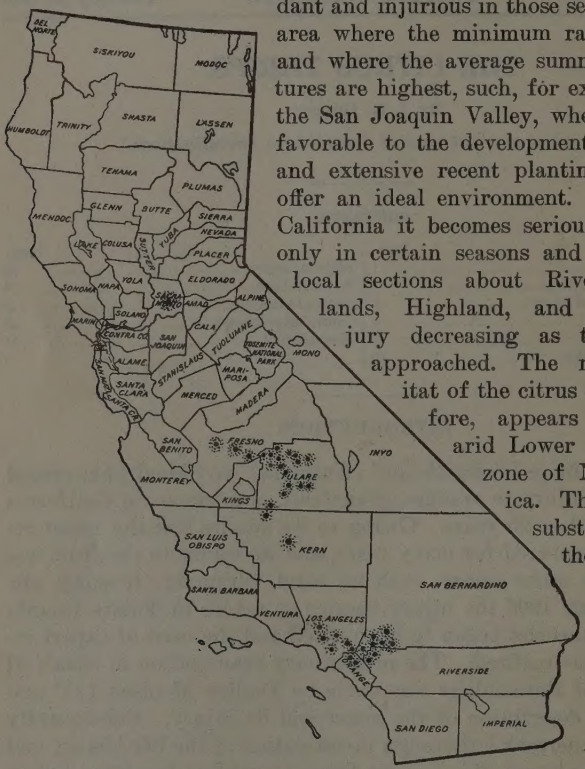


FIG. 1.—Map showing present known distribution of the citrus thrips (*Scirtothrips citri*) in California. (Original.)

Although the insect occurs in injurious numbers in Arizona, thus far it has been taken only in the Salt River Valley near Phoenix and Mesa (fig. 2). Dr. A. W. Morrill informed the writer by letter that he thought he detected traces of thrips injury in an orange grove near Yuma, but specimens have not been taken there.

POSSIBILITY OF ITS OCCURRENCE ELSEWHERE.

No verified reports of the occurrence of the citrus thrips in States or countries other than the foregoing have been made, although it is said to occur at Hermosillo, Sonora, Mexico. There are various reports of thrips injuring citrus fruits, the species concerned being often in doubt. Thus, Tower[1] states that certain scars found on oranges in Porto Rico probably are caused by thrips which were present in the trees in great numbers, but the identity of the thrips is not given. Rolfs, Fawcett, and Floyd[2] describe injury to oranges in Florida by a thrips which appears to be *Frankliniella* (*Euthrips*) *tritici* Fitch, if indeed the injury illustrated by them is caused by thrips. The citrus thrips does not occur in southern Louisiana, and doubtless could not thrive there because of the high humidity and heavy rainfall, and for the same reason probably does not occur in Florida.

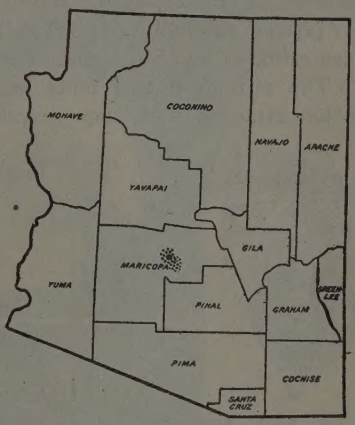


FIG. 2.—Map showing present-known distribution of the citrus thrips in Arizona. (Original.)

NATURE AND EXTENT OF INJURY.

The citrus thrips obtains its food by puncturing the tissues and draining the contents of the cells, causing the cell walls to collapse. Growth expansion of the surrounding living cells leaves the punctured and dead areas sunken and distorted. The very characteristic scabbing of the fruit is caused by the dead and dry cell walls being forced outward by the growing cells beneath, the resultant scabs often covering a large portion of the rind. The various rings, streaks, splashes, and other patterns in the tissues result from the almost incessant movement of the thrips as they feed (Pl. I). The

[1] Tower, W. V. Insects injurious to citrus fruits and methods for combating them. Porto Rico Agr. Exp. Sta. Bul. No. 10, p. 20. 1911.

[2] Rolfs, P. H., Fawcett, H. S., and Floyd, B. F. Diseases of citrus fruits. Fla. Agr. Exp. Sta. Bul. 108, p. 32–33. 1911.

"stem-end ring" is the most characteristic form of fruit injury, and is caused by the thrips feeding and ovipositing in a circle under the protection of the sepals when the fruit is small, the injury expanding as the fruit grows. Injury resulting from feeding punctures in mature fruits appears as brownish, glossy discolorations due to cell sap drying on the surface. A large proportion of the badly marked fruit is undersized owing to failure to mature normally, and much of it is at times distorted by failure of the injured tissues to grow.

The more characteristic injury to the leaves is the grayish streaks and areas (Pl. II, fig. 2) and curling. At times cuplike depressions or pockets resembling aphid galls are formed, but oftener the leaves are crinkled or even tightly curled (Pl. II, figs. 1 and 3).

The unfolding leaf buds and especially the terminal buds are often attacked with such severity as to cause them to wither and die, these turning brown or black and finally dropping off.

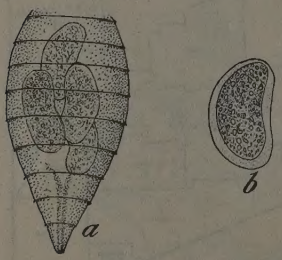


FIG. 3.—*a*, Eggs of the citrus thrips in situ; seen through the abdominal wall. *b*, Single egg of the citrus thrips. Highly magnified. (Original.)

DAMAGE TO FRUIT.

DROPPING.

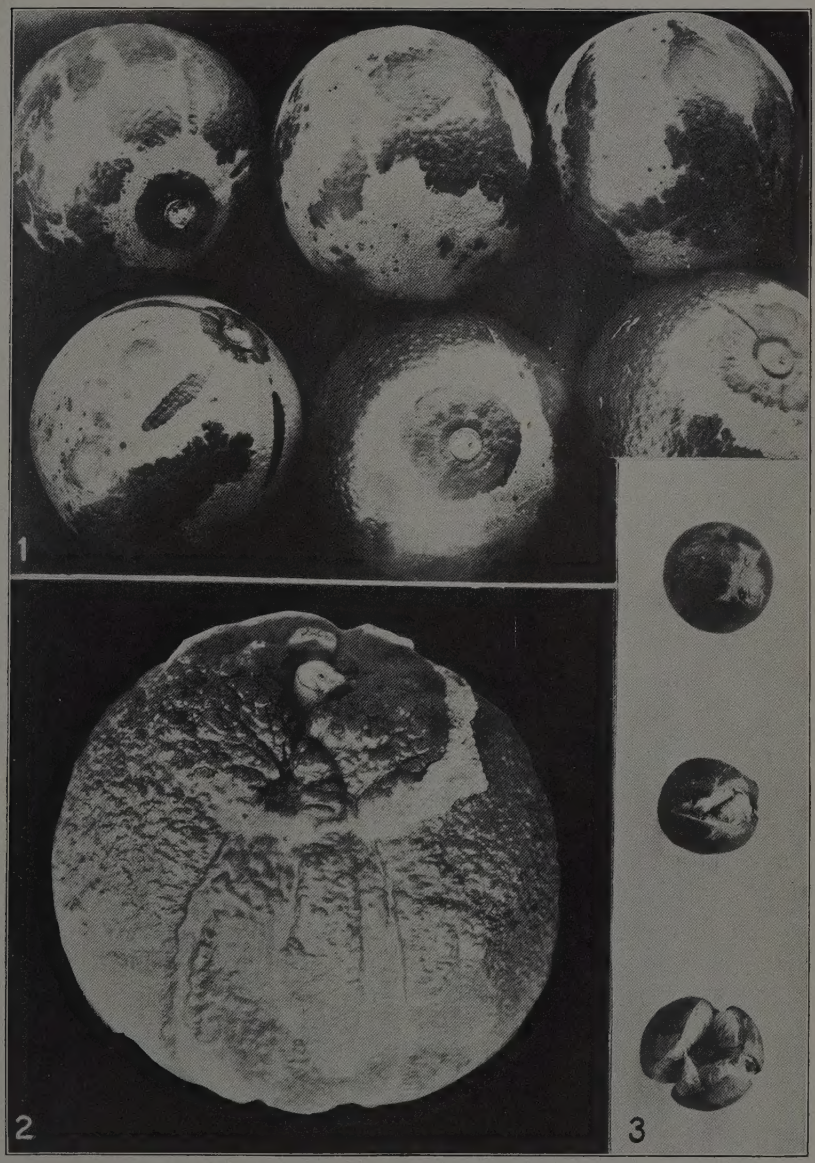
In exceptionally severe infestations, much of the young fruit is punctured over its entire surface during the first three weeks following the blossoming period and thus is prevented from acquiring normal growth, the little fruits eventually dropping to the ground. An appreciable percentage of the crop is lost in this way in certain orchards of Tulare County, Cal., in certain years.

SPLITTING.

While only a small proportion of the usual fruit splitting is caused primarily by thrips, a certain amount of splitting of young oranges does occur every season as a result of the long-continued feeding of thrips over an area usually near the navel end of the fruit. The affected tissues die and dry out and the scabbed area, unable to expand with the growing fruit, cracks (Pl. I).

MALFORMATION.

From less than 1 to as much as 6 per cent of the orange crop, depending upon the orchard and the season, is so badly deformed by the citrus thrips that it must be culled out and sold at the packing house for whatever it will bring. The better culls usually command



CHARACTERISTIC DAMAGE BY THE CITRUS THRIPS (SCIRTOTHRIPS CITRI).

FIG. 1.—Typical citrus thrips scabbing on young oranges. (Natural size.) FIG. 2.—Unusual form of thrips injury on rough orange. FIG. 3.—Splitting of young oranges due to thrips injury. (Original.)

DAMAGE TO THE FOLIAGE OF CITRUS BY THE CITRUS THRIPS.

FIG. 1.—Orange leaves distorted and tightly curled by the citrus thrips. FIGS. 2 and 3.—Orange leaves "cupped" by the citrus thrips, showing streaks of dead and discolored tissue. (Original.)

25 cents per box. Although in seasons such as 1911 only a small percentage of the fruit is culled from this cause, in one instance an entire shipment of navel oranges from a 5-year-old, untreated orchard was refused at the eastern market, with the statement that the oranges were too badly scabbed to be salable. In several other orchards inspected that year from 1 to 2 per cent of the fruit was malformed as the result of thrips feeding.

GRADE REDUCTION.

The most important damage resulting from the feeding of thrips upon trees that have passed the period of rapid growth is the lowering of the market value of the fruit by unsightly scabbing and scarring. Although the eating quality of the orange is not affected thereby, its commercial grading is lowered considerably and the selling price correspondingly reduced.

EXTENT OF DAMAGE TO ORANGES IN TULARE COUNTY.

In 1909 more than 80 per cent of the oranges of Tulare County, Cal., were so damaged by the citrus thrips as to lower the grade; in 1910 the grading affected about 63 per cent of the crop, and in 1911 about 65 per cent was affected.

To calculate the loss due to grade reduction because of damage by thrips it is necessary to know the method of grading and relative value of the grades. In California oranges usually are packed in either three or two grades. In the 2-grade pack the quality of the fruit of the first grade is about the same as would be obtained by placing together the first and second grades of the 3-grade pack, the quality being sufficiently lowered to include fruit which would be of second grade in a 3-grade pack.

Taking the season of 1911 as fairly representative of recent years, returns received by different packing houses on a total of about 358,000 boxes of oranges of all grades indicate the following price range between the different grades. First-grade fruit average 37 cents more per box than second grade; the latter 28 cents more than third grade. Receipts from several carloads of fruit shipped in two grades gave an average difference of 51 cents per box in favor of the first grade. Examination of thousands of boxes of oranges throughout the district from Mount Campbell to Porterville showed 34 per cent of the fruit to run first grade, 43 per cent second grade, and 23 per cent third grade, so far as thrips marking was concerned.

Statistics on the amount and value of the total orange crop shipped from the entire San Joaquin Valley in 1911 are not available, but from Lindsay and its tributaries, constituting much the largest single citrus section of the valley, 1,525 carloads, or about 594,750

boxes, of navel oranges were shipped. The loss suffered from grade reduction due to thrips by the Lindsay district alone, and in a season of comparatively light infestation, was therefore about as follows: Forty-three per cent, or 255,742 boxes, reduced to second grade at a loss of 37 cents per box, making $94,624.54; and 23 per cent reduced to third grade at a loss of 65 cents per box, making an additional $88,914.80, or a total loss of $183,539.34.

EXTENT OF DAMAGE IN SOUTHERN CALIFORNIA.

It is calculated that from 20 to 40 per cent of the 1910 orange crop of Riverside County was sufficiently marked to keep it out of first grade. The injury was most severe in groves in the hills to the south and east of Riverside and in the vicinity of Highgrove, where conditions are similar to those along the foothills in the San Joaquin Valley. In this section about 55 per cent of the crop was lowered in grade because of thrips marking. Of the 1911 crop in the same groves, however, only 16.9 per cent was marked sufficiently to throw it out of the first grade.

At Redlands the injury was somewhat less severe than at Riverside. Only from 2 to 5 per cent of the first-grade fruit running in the packing houses was marked, and that slightly, while from 50 to 60 per cent of the second-grade fruit was more seriously damaged. The writer was informed that fruit from some of the groves was injured more severely than that then passing, and when such fruit was being packed an additional or third grade was added to accommodate the thrips-marked oranges.

In the Pomona-Claremont-Upland section damage by the citrus thrips was much less severe than at Riverside and Redlands. The grades of fruit then running were "fancy" and "choice," and it was estimated that about 10 per cent of the first-grade oranges had traces of marking and about an equal percentage of the second, or choice, fruit was more conspicuously marked. The most severe marking occurred at Claremont, which is nearer the hills, a little warmer, and produces very vigorous trees. First-grade fruit was scarred about equal to that at Pomona, but a third grade was run at Claremont, about 25 per cent of which had been reduced because of thrips scabbing.

The injury decreases toward the coast, so that at Whittier only about 10 per cent of the entire crop was scabbed. About 2 per cent of the first and 5 per cent of the second-grade fruit had been slightly marked. Less than 1 per cent of the marked fruit of second grade would be placed in that grade because of thrips injury alone. Lemons were blemished about as much as oranges. At Pasadena 90 per cent of the 2,000 oranges examined in the field was entirely free from

thrips marking; 9.5 per cent had received a few scratches which would in no way affect their value, and only a few oranges were characteristically and severely marked.

INJURY IN ARIZONA.

The amount of thrips injury to citrus in Arizona varies greatly in different groves, depending upon the health and vigor of the trees. It has never been as serious in Arizona as in the San Joaquin Valley, Cal. In the poorer conditioned groves the fruit injury varies from none to 25 per cent scarred sufficiently to reduce the grade. In some seasons the injury has run much higher than this in certain groves. Thus Morrill (9) in 1912 stated that in the various groves injury to the 1911 orange crop ranged from none to about 60 per cent scarred sufficiently to affect the market value, and calculated that there was a 28 per cent reduction of oranges to second grade and a 25 per cent to third grade, and that about 1 per cent were culled partly or entirely because of thrips marking.

INJURY TO TREES.

In many orchards in the San Joaquin Valley the foliage was subjected to prolonged attack from thrips until the functions of the leaves became so disturbed that the trees were prevented from reaching their normal size and fruiting capacity. Stunting due to thrips feeding begins in the nursery. In seasons of severe infestation the leaves and stems of nursery trees are so badly scarred and twisted as to appear blighted, preventing sale at a fair price, and often the growth of the trunk is so retarded that the trees must be held a year or more beyond the proper time for sale in order to meet the size requirements. It sometimes happens that this class of stock is sold along with better trees and, thrips attacks continuing for several years in the orchard, the trees remain undersized and relatively unproductive.

DISSEMINATION.

The spread of the citrus thrips from one citrus-growing section to another is accomplished mainly in the egg stage. The shipping and planting of nursery trees occurs principally from February to May, the transfer of trees being well under way before first-generation larvæ begin to issue from the eggs deposited the preceding fall. Quarantine inspection is entirely inadequate to prevent the introduction of the insect into new districts, since it is practically impossible to detect the eggs of the species. Complete defoliation of the trees prior to shipment accomplishes the destruction of many of the overwintering eggs, but a proportion of them escape because of insertion into the bark of the smaller branches.

A few eggs also pass the winter in the ripening fruit and are thus distributed to practically every part of the United States. Some of these eggs may hatch and survive from fruit marketed in tropical and subtropical climates, but there is very little danger of the insects becoming established in any of the localities where oranges are marketed generally.

Thrips larvæ are to some extent distributed on nursery stock and, though not so difficult to detect as eggs, would be overlooked very largely in commercial inspection because of their minute size and habit of hiding in crevices in the bark. It is probable that occasionally the larvæ are shipped on fruit, especially on the Valencia orange, but nearly mature fruit has little attraction for them, and it is further probable that few survive the handling incidental to picking and packing.

Local spread is accomplished largely by flight. The citrus thrips is a very ready flier when disturbed or when it desires better food. An observer standing in a favorable position with regard to the light may see numbers of these minute insects leave one tree and make for another, usually disappearing at a distance of 4 or 5 feet because of the light not striking just right. The insect will leave either tree or orchard as soon as leaves, stems, and fruit become somewhat tough. Thus in a grove of young Valencia trees where thrips were present to the number of 80 to 150 per leaf at one examination, not a single adult thrips could be found two weeks later. The explanation was that the leaves had hardened and were no longer suitable as food, while on some older navel trees near by a luxuriant growth of leaves had just reached prime condition for food, and here the insects were found in as large numbers as they had been found on the trees they had deserted.

The citrus thrips usually takes a rapid spiral or zigzag course in short-distance flights, but in extended flights the course is more direct. The flight somewhat resembles that of katydids and grasshoppers. By mounting in a strong wind the thrips undoubtedly would fly a mile or possibly more.

FOOD PLANTS.

Although the citrus thrips thrives best and reaches its maximum abundance on plants of the citrus group, it feeds continuously or occasionally on plants widely separated botanically from the citrus group. In Table I the food plants are arranged according to the extent of infestation as nearly as possible in the order of their importance as food for thrips. There is very little difference, however, in the extent to which the different plants in Group III are infested, and certain plants in Group II are infested almost as badly as any of the citrus fruits of Group I. It will be noted in Table I that the

DAMAGE TO CITRUS AND GRAPES BY THE CITRUS THRIPS.

FIG. 1.—Lemons injured by the citrus thrips. FIG. 2.—Pomegranates injured by the citrus thrips. FIG. 3.—Grapes scarred by the citrus thrips. (Original.)

range of food plants is wide and includes practically all the citrus fruits grown in California, certain deciduous fruits and nuts, a few ornamentals, and several noncultivated plants.

TABLE I.—*Food plants of the citrus thrips in order of importance.*

Group I, generally infested.	Group II, occasionally infested.	Group III, rarely infested.
1. Sweet oranges.	6. Pomegranate (*Punica granatum*).	11. Peach.
2. Mandarin orange (*Citrus nobilis*).	7. Grape.	12. Plum.
3. Pomelo, or grapefruit.	8. California pepper tree (*Schinus molle*).	13. Pear.
4. Lime and lemon.	9. Chinese umbrella tree (*Melia azedarach umbraculifera*).	14. Raspberry.
5. Kumquat (*Citrus japonica*).	10. Apricot.	15. Pecan.
		16. Walnut.
		17. Olive.
		18. Rhubarb.
		19. Dock (*Rumex* sp.).
		20. Purslane (*Portulaca oleracea*).
		21. Willow.
		22. Wild morning-glory (*Convolvulus* sp.).
		23. Nightshades (*Solanum* spp.).
		24. Almond.
		25. Tumbleweed (*Amaranthus* sp.).

The sweet oranges suffer greatest damage from the citrus thrips, especially the varieties known as Washington, Thompson's Improved, and Australian navels, and the Parson Brown and Homosassa. Valencias are damaged considerably when the trees are young, and the fruit is attacked at all times, but not severely. Blood oranges generally escape with very little injury. The Washington navel orange covers a greater acreage in Tulare County than all other varieties together. This fact probably accounts for this variety holding first rank as a food plant of the thrips. As a rule not more than 25 per cent of the Valencia crop is injured sufficiently to depreciate its market value; and it is rarely that more than 10 per cent of blood oranges show any marking whatsoever. Oranges of the Mandarin group, especially the tangerines, are subject to very severe marking, for the reason that they remain attractive to thrips until nearly mature. The Satsuma often becomes much distorted because of thrips marking, but this fruit is an unimportant crop in California. Pomelos, limes, and lemons (Pl. III, fig. 1) share nearly equally in severity of thrips marking, but the trees are not often severely injured, as the foliage is not particularly attractive to the insect. Limes often become severely scarred, the rind remaining tender throughout the growth of the fruit. Of all the citrus fruits the kumquat is the least attractive to thrips, rarely more than from 2 to 5 per cent of the fruit becoming slightly scarred by them.

The pomegranate (Pl. III, fig. 2) is the most preferred fruit other than citrus. Pomegranate trees mostly are planted as ornamentals bordering citrus groves, but in 1910 in a 20-acre pomegranate orchard at Lindsay, Cal., 75 per cent of the fruit showed the characteristic scabbing of the citrus thrips. Pomegranates of clear, red

color natural to the ripe fruit are rare in that section, a blending or streaking of the natural red and the gray thrips injury being characteristic. The grape (Pl. III, fig. 3) ranks next to the pomegranate in degree of infestation. It is attacked mostly during the period between growths of the orange. Both leaves and fruit suffer, but chiefly the fruit. In 1911, when citrus trees made but slow and scant growth, a case of severe injury to a small vineyard of Malaga grapes was reported to the writer. This vineyard was located among orange trees which had grown very little during the summer, and the thrips had concentrated there, scarring a large percentage of the berries and distorting many leaves.

Apricots, peaches, plums, and pears are attacked more rarely; raspberry, very rarely. A part of the scabbing found on the pear is probably due to other species of thrips, although new pear leaves occasionally have been found so badly curled by *Scirtothrips citri* that they looked diseased.

The California pepper tree and the Chinese umbrella tree are both very attractive to the citrus thrips, which become abundant on them at certain times of the year. Neither of these trees show the effect of thrips injury from a distance, as do orange trees, and though oviposition takes place in both varieties eggs are not deposited in umbrella-tree leaves in the fall. The insects do not attack the small, berry-like fruit of the pepper tree.

The remaining food plants listed in Table I are attacked but rarely and some of them (almond, walnut, and tumbleweed) are probably only accidental food plants. More thrips have been found occasionally on the common dock than on any other of the noncultivated plants.

LIFE HISTORY AND HABITS.

THE EGG.

DESCRIPTIVE.

The egg (fig. 3), as seen in position through the translucent body wall of the parent thrips, is a bluish-white, bean-shaped object measuring on an average about 0.185 mm. in length by 0.085 mm. in width. It is comparatively very large, so that five eggs in an advanced stage of development occupying the ovaries at the same time cause considerable distention of the abdomen.

When freed from the ovaries, immediately after deposition, the egg is thick at the base, with the upper two-thirds gradually drawn out into a narrower, necklike portion. The color is then clear ultramarine and the surface is smooth and glistening. The membrane is flexible, so that the egg may assume other shapes within certain limits. As the embryo develops the bright-red eyes become visible through the transparent shell.

INCUBATION PERIOD.

The time required for the development of the egg after deposition varies considerably at different times of the year and is influenced largely by the prevailing temperature. There is also some variation among eggs deposited the same day, in the same plant, and kept under precisely the same conditions of temperature. The incubation period ranged from a minimum of 6 days to a maximum of 24 days, the average for the entire season being 16 days. The records on incubation in 1911 are given in Table II. The principal average seasonal variations, together with the prevailing mean temperatures for the periods covered, are shown in Table III. It will be seen that in the cool weather of spring and early summer and again in the fall the incubation period is about two and one-half times as long as in the hottest period of summer. In like manner the egg stage and other immature stages as well are short in exceptionally hot, dry summers, such as those of 1908 and 1909, and considerably prolonged in cooler years, such as 1911.

TABLE II.—*Incubation period of the citrus thrips, Lindsay, Cal., 1911.*

Record No.	Number of eggs.	Deposited.	Hatched.	Duration of stage.	Record No.	Number of eggs.	Deposited.	Hatched.	Duration of stage.
				Days.					*Days.*
1	11	May 4	May 21	17	18	1	May 9	May 26	17
2	61	do	May 22	18	19	1	do	May 27	18
3	15	do	May 23	19	20	1	do	May 28	19
4	6	do	May 24	20	21	1	July 17	July 23	6
5	2	do	May 25	21	22	1	do	July 24	7
6	1	do	May 26	22	23	2	July 22	July 28	6
7	1	do	May 27	23	24	1	do	July 29	7
8	1	do	May 28	24	25	1	do	July 30	8
9	8	May 5	May 21	16	26	1	Aug. 1	Aug. 9	8
10	31	do	May 22	17	27	1	do	Aug. 10	9
11	2	do	May 24	19	28	1	Sept. 6	Sept. 23	17
12	11	May 6	May 22	16	29	3	Sept. 8	Sept. 21	13
13	7	do	May 23	17	30	2	do	Sept. 22	14
14	5	do	May 24	18	31	2	do	Sept. 24	16
15	3	do	May 25	19	32	1	Sept. 18	Oct. 8	20
16	1	do	May 27	21	33	1	do	Oct. 10	22
17	1	May 9	May 25	16					

	Days.
Maximum	24
Minimum	6
Average	16

TABLE III.—*Principal seasonal variations in incubation of eggs of the citrus thrips, Lindsay, Cal., 1911.*

Period of season.	Range.	Average.	Mean temperature.
	Days.	*Days.*	° *F.*
May 4 to May 28	16–24	18.8	64.06
July 17 to Aug. 10	6–9	7.3	81.52
Sept. 6 to Oct. 10	13–22	17.0	62.18

HATCHING.

When ready to hatch, the upper end of the eggshell is broken and the larva pushes through. The first impression on watching a larva issue from the leaf is that the egg itself, or a minute white worm, is being pushed out through the epidermis, the only movement visible being a forward one. When the head and thorax are free, the larva begins a series of vigorous spiral movements which soon liberate the legs and antennæ. In some instances the antennæ retain the folded position until the larva has freed itself completely from the tissue. When the legs are free the insect pushes straight down against the leaf with the third pair of feet and, alternating with abdominal movements, brings itself into position to bend forward and clasp the leaf. It then readily pulls itself out. The entire operation requires from 5 to 10 minutes.

FIG. 4.—First-instar larva of the citrus thrips. Highly magnified. (Original.)

Hatching is not much affected by drying of the leaf or stem tissue. Larvæ have issued from leaves several days after the latter had become thoroughly wilted, and from stems as long as 21 days after they had been cut from the tree.

THE LARVA.

DESCRIPTION.

First-instar larva.—Just after emergence the larva (fig. 4) is colorless and translucent. The head, antennæ, mouth parts, and legs are disproportionately large, giving it an ungainly appearance. The eyes are bright red. The average length is 0.26 mm. (about 0.01 inch). The most distinctive character of the first-instar larva is the narrow, tapering abdomen. In a day or two the body becomes suffused with yellow, which gradually deepens to orange in the fully developed larva. As growth progresses, the head and appendages lose their ungainly appearance and become more symmetrical, and the abdomen grows plumper and less sharply tapering. Shortly before molting to the second instar the average length is 0.45 mm. (about 0.017 inch).

FIG. 5.—Second-instar larva of the citrus thrips. Highly magnified. (Original.)

Second-instar larva.—The second-instar larva (fig. 5) is similar in general appearance to the first, except that it is more robust, more densely pigmented, and the abdomen is broadly spindle-shaped, tapering gradually from the middle segments in both directions. The color varies from light yellow to deep orange yellow, and occasionally cream-colored in-

dividuals occur. The eyes are dull red to dark purple. The average length varies from 0.45 mm. (about 0.017 inch) at the beginning of the instar to 0.90 mm. (about 0.035 inch) just before molting to the propupa.

FEEDING HABITS.

The larva becomes active immediately after emergence, moving about over the leaf or stem, swinging the antennæ up and down, and surveying its surroundings for a place to feed. When feeding, the citrus thrips does not insert the mouth-cone itself into the plant tissues, and thus does not cause holes and raggedness in the leaves, as the pear thrips does, for example. The feeding puncture of the citrus thrips is made by bringing the tip of the cone into contact with the surface of the plant and moving the head quickly downward and slightly backward. This movement results in a slight folding, or elbowing of the cone at a point near its juncture with the head and in some way exerts a leverage upon the lancets, which are thus pushed into the tissue, starting the flow of cell sap, which is sucked up through the tubular interior of the cone.

DURATION OF LARVAL FEEDING STAGE.

The first of the two instars or stages of growth of the larva ranged from a minimum of 1 day to a maximum of 13 days, with an average of 3.7 days, in specimens in which the actual casting of the skin was observed. The second instar of these specimens ranged in duration from 2 to 9 days, with an average of 4 days. An abnormal maximum of 29 days was reached by one specimen in November, the insect ultimately dying from exposure to prolonged low temperatures, without changing to the propupa. The two larval instars may be said to be of about equal duration.

The duration of the complete or feeding stage of the larva ranged from 3 to 21 days, the average for the entire period from March 25 to November 5 being 7.8 days. Great individual variations in the length of the immature stages are to be expected and do not have any particular significance in a practical way, but a knowledge of the average variation in different periods of the season and in different seasons, due largely, as they are, to climatic factors, are of value in predicting what the severity of a given infestation will be. The principal seasonal variations in the duration of the larval stage, with a record of the prevailing temperature, which is the principal factor affecting the length of the stage, are given in Table IV. It will be seen that in seasons such as 1911 the larval stage will range from about 4½ to 7 or 8 days in the period from about the middle of May to the middle of September, and in the cooler weather of March and April

and from the latter part of September to November it will range from about 12 to 14 days.

TABLE IV.—*Seasonal variations in duration of the larval stage of the citrus thrips, Lindsay, Cal., 1911.*

Period of season.	Average duration of the larval stage.	Prevailing mean temperatures.
	Days.	° *F.*
Mar. 25 to Apr. 15	13.7	59.62
May 13 to June 3	8.2	62.58
June 13 to Sept. 5	4.4	74.61
Sept. 4 to Sept. 21	6.8	67.47
Sept. 23 to Nov. 5	11.8	58.48

MOLTS.

All four molts of the citrus thrips, comprising two in the larval stage and two in the pupal stage, are accomplished in about the same manner. The first molt takes place on the leaves and fruit of the host plant, the remainder in some secure hiding place, usually on the ground. When ready to molt the larva ceases to feed and becomes inactive. Tremors vibrate the antennæ and body at brief intervals for a period of from one to three hours, and the abdomen slowly contracts and shrinks away from the old skin. Then follows an active period of from 15 minutes to an hour, in which the middle and hind legs are repeatedly stretched as far back as possible and slowly drawn forward, while the insect goes through jerky lateral motions with the body. The skin then splits from the vertex along the dorsum to the abdomen, after which the insect becomes very active, doubling down with the head between the fore feet and slowly removing the skin from the head and antennæ. The legs are then worked out of their casings and the exuvium pushed back under the body. The skin usually is attached at the tip of the abdomen to the surface on which molting occurs, greatly aiding the insect in extricating itself. The skin generally is removed entire, but occasionally antennal and leg casings are removed separately. Cool weather greatly retards the process, which is more likely to be observed when such weather prevails. Groups of larval skins resembling specks of gray dust sometimes are found on orange leaves. The molting process in the citrus thrips is similar to that observed in certain Orthoptera.

THE PUPA.

DESCRIPTION.

The propupa.—The propupa, or first instar (fig. 6), is very similar in general appearance to the larva. It is generally somewhat paler

in color. The antennæ are directed forward and are 4-jointed. The eyes, at first almost colorless, finally show a red pigmentation in about two-thirds of the facets. The wing pads, which are almost colorless, transparent saclike projections, the hind pair projecting slightly farther than the fore pair, extend to or slightly beyond the hind margin of the second abdominal segment at the beginning of this instar and reach to the hind margin of the third segment before transformation to the second-instar pupa.

FIG. 6.—First-instar pupa of the citrus thrips Highly magnified. (Original.)

The second-instar pupa.—The second-instar pupa (fig. 7) is at first but slightly larger than the advanced propupa. The color is pale, translucent yellowish. The antennæ are apparently 4-jointed, but the exact number of joints is confused by the ringed appearance due to transitional tissues seen through the pupal sheath. They are directed backward over the head and prothorax, extending to a point near the middle of the latter. All facets of the eyes are red pigmented. The ocelli are visible and translucent. The wing pads at first extend to the hind margin of the sixth abdominal segment or slightly beyond, but project as far as the ninth or tenth segment just before the molt to the adult. Long weak spines are moderately conspicuous on antennæ, legs, and hind angles of the abdominal segments.

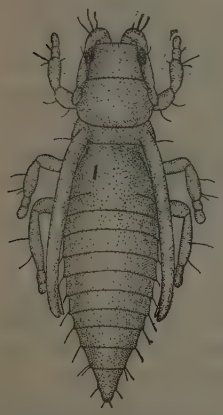


FIG. 7.—Second-instar pupa of the citrus thrips. Highly magnified. (Original.)

There is less growth in the pupal stage than in the larval stage. The average length soon after the molt to the propupa is 0.70 mm. (about 0.027 inch); shortly before the first pupal molt it is 0.72 mm. Just before the last molt it averages 0.80 to 0.84 mm. (about 0.03 inch). The wing pads increase on an average about 0.04 mm. in length during the first instar, and show a gain after molting to the second instar of 0.10 to 0.12 mm. After the molt to the adult stage the wings exceed the tip of the abdomen.

PLACE OF PUPATION.

Certain Thysanoptera, notably the pear thrips, congregate in large numbers during pupation, and a knowledge of this habit may lead to a means of effective control. The citrus thrips, however, has no definite place of pupation. The second-instar pupa is more exposed to the attacks

of predatory insects than any other stage, and therefore pupation occurs in places practically inaccessible to any but the smallest insects and mites. The pupæ are scattered widely, thus limiting the possibility that any great number will be destroyed at one stroke. They have been found in the following situations: On the ground under the trees; in curled, dried leaves, and under a mat of fine cobweb and dust on dry leaves; in the split tips of leaf stems; in small crevices in the bark of dry twigs. In clean-cultivated young orchards, where but few dead leaves and twigs collect, the thrips pupate in crevices near the base of the trunks, under dead and living fluted scales (*Icerya purchasi* Mask.), and in similar obscure situations. In only two instances was pupation found to have occurred on the upper part of the tree: One in which a propupa was found in a distorted leaf, and another in which one specimen occurred under the cocoon of a caterpillar on an orange leaf. To find pupæ of the citrus thrips requires a minute and painstaking search. If no better shelter offers, the insect gathers particles of dust, wood, leaves, etc., about itself, effectively concealing it. In captivity a large proportion of the pupating specimens crawled into the cotton plugs of the rearing bottles and under the split bark at the ends of orange stems used as food. No food is taken during the pupal stage.

DURATION OF THE PUPAL STAGE.

The duration of the pupal instars may be accurately determined, as once a spot has been chosen for pupation the insect seldom moves from it, and cast skins of the last larval and both pupal transformations generally remain nearby. The first pupal instar ranged from 1 to 9 days, with an average for the entire active season, from April 1 to November 8, of approximately 2 days. The second instar ranged from 1 to 25 days, with an average of 5.5 days for the period from April 4 to December 2. The 25-day maximum period is of course exceptional, and would occur in comparatively few individuals of very late hatch.

The entire variation in duration of the complete pupal stage in the period from April 1 to December 2 was from 2 to 28 days, with an average of 7.5 days. The important general variations in the length of the pupal stage in different periods of the season are shown in Table V. It will be seen that growth of the pupa, as well as of the egg and the larva, is slow in the cool weather of spring and fall, when the temperature ranges between 50° and 60° F., and that it is considerably accelerated in midsummer, with temperatures above 60° F.

TABLE V.—*Seasonal variations in duration of the pupal stage of the citrus thrips, Lindsay, Cal., 1911.*

Period of season.	Average duration of the pupal stage.	Prevailing mean temperatures.
	Days.	°*F.*
Apr. 8 to Apr. 26	13.2	56.52
May 3 to May 13	8.4	58.08
May 22 to June 4	5.5	64.74
June 2 to Sept. 5	3.5	76.55
Aug. 31 to Sept. 26	5.3	68.20
Sept. 21 to Oct. 28	7.3	60.70
Oct. 18 to Dec. 2	15.4	51.04

THE ADULT.

DESCRIPTION.

The adult citrus thrips (fig. 8) is among the smallest of insect pests and is smaller than most of the more injurious related Thysanoptera. The female measures from 0.60 to 0.88 mm. (about one-fiftieth to one-twentieth inch) in length; the male, which is noticeably smaller, measures from 0.51 to 0.65 mm. The color of the adult is translucent

FIG. 8.—The adult female citrus thrips. Highly magnified. (Original.)

orange-yellow; the male is somewhat paler than the female. The head is small, about one-half as long as wide, and a considerable portion of it is occupied by the large compound eyes, which are dark purple to black. Three transparent ocelli, or simple eyes, bordered by reddish brown crescents, occupy the space between the compound eyes on the upper surface of the head. The antennæ are 8-jointed; some of the segments are furnished with transparent sense organs.

The rostrum, or mouth-cone, is short and blunt, not quite reaching across the prothorax, and is tipped with black. The prothorax is slightly wider than the head, slightly narrower than the mesothorax. The female is broadest through the middle segments of the abdomen, tapering gradually both ways; tip of the abdomen conical, fitted with a sawlike ovipositor. The abdomen of the male tapers gradually from the second segment to the tip, which is bluntly rounded; a pair of reddish brown testes is visible through the body wall at the sixth and seventh segments. More or less conspicuous spines occur on the wings and near the hind angles and at the tip of the abdomen. Under high magnification the abdomen is seen to be regularly beset with minute hairlike processes.

DURATION OF ADULT LIFE.

Owing to their extreme activity, minuteness, and delicacy, many of the adult thrips under observation were killed accidentally and others probably injured in changing their food. For this reason only the data upon specimens which lived 20 days or longer are considered in discussing the length of adult life. In only a small percentage of the cases considered did the length of life run as low as 20 days. The maximum duration was 49 days, which is also probably exceptional. The variation of 29 days occurring between the accepted minimum of 20 and the maximum of 49 days is probably as great as ever occurs in the field among specimens not affected by accident, disease, or enemies. In nearly 70 per cent of the cases considered the insects lived 25 days or more, and in 85 per cent they lived 35 days or less. The average age attained by the shortest-lived specimens may therefore be set safely at 25 days, and that of the longest lived at 35 days, the mean between the two being 30, which corresponds closely with the general average from all which lived over 20 days. The insects lived only from 3 to 6 days without food.

INFLUENCE OF THE WEATHER ON GROWTH AND BEHAVIOR.

The citrus thrips is purely a product of the arid Southwest and flourishes only in a hot sunny climate. The fact that it does not thrive in coastal sections nor in any part of the humid belt of the Lower Austral life zone shows its sensitiveness to conditions of temperature and moisture. The insect flourishes best on sunny hill slopes. It appears to enjoy the direct rays of the sun, and by preference seeks the more exposed leaves and fruits in the upper and southerly expansion of the trees. On bright warm days of summer the adults exhibit marked restlessness and increased reproductive activity. The duration of the immature stages is shortened, molting is accelerated, and the rate of emergence is increased greatly. The

number of generations is greater in exceptionally long hot summers than in more moderate ones.

Cool, cloudy, or rainy weather, on the other hand, at once markedly diminishes the various activities of the insects. They then seek shelter in groups in the pits or curls and on the underside of the leaves, about the stem ends of the fruit, and in the crotches and angles of the stems. Growth, molting, and emergence are retarded. With temperatures ranging between 40° and 50° F., in November and December, larvæ and pupæ often live fully a month without change, scarcely feeding at all, and as the weather continues to grow colder both they and the adults die off, leaving only unhatched eggs to produce the succeeding spring generation.

PECULIARITIES OF INFESTATION DUE TO FEEDING HABITS OF THE ADULT THRIPS.

Feeding only upon the newer tissues, the adult citrus thrips are active in selecting young and healthy trees and often suddenly migrate from one set of trees to another or from one orchard to another. In localities where, owing to favorable cultural conditions and large plantings of young trees, an abundance of new shoots occurs in a close succession of growths, adults will congregate in immense numbers and remain throughout the season. The resultant damage in such localities is often entirely out of proportion to that occurring in other parts of the same district. The explanation of excess infestations in certain orchards and in certain localities is simply food preference. Areas of this sort occur typically along the foothill slopes, both in the San Joaquin Valley and near Riverside and Redlands.

In older orchards, where some of the trees have been cut back and rebudded, thrips will congregate on the watershoots and buds from every part of the orchard and in such numbers as greatly to retard the growth of the buds. The damage done in old orchards surrounded by young trees is often very slight for the reason that the thrips confine themselves almost exclusively to the latter. In seasons like 1911, when the climatic conditions are such as to minimize growth, the insects are compelled to feed to a greater extent upon the fruit with consequent greater damage.

OVIPOSITION.

DESCRIPTION OF PROCESS.

The following is a description of oviposition under natural conditions as observed in a single specimen at night during cool weather, the observations being made with the aid of an electric pocket lamp and a hand lens. Attention was first attracted to the specimen by its indifference to the light. For a half hour it remained in a space

about an inch square and went through the following antics: Frequently it would elevate the abdomen, spreading the wings as in preparation for flight. Then it would crouch flat to the leaf, twisting the abdomen about with a rotary motion, at times leaning far over to one side and often moving backward, slowly turning about in a complete circle. At one time the insect turned completely over and lay on its back for a short space, the abdomen continuously moving as described. At the end of a half hour the ovipositor was slightly exserted from a point very near the tip of the abdomen, which was then arched and its tip brought into contact with the leaf surface. The ovipositor was then inserted in the leaf in a single movement from an almost vertical position to about two-thirds its length. The insect then relaxed slightly and remained quiet in this position for four minutes, when it moved away and rested. Only one egg was deposited.

PORTION OF PLANT SELECTED FOR OVIPOSITION.

The citrus thrips oviposits only in those tender tissues which are suitable for food, i. e., the new growth and the young fruit. Eggs are deposited largely in the leaves and fruit in summer and in the stems in fall, more particularly the large tender stems of the orange tree. In summer large numbers of eggs are thrust into the new leaves, leaf stems, fruit and fruit stems, and when the petals have fallen the fruit receptacles become a favorite place of oviposition, which is accomplished under the protection of the sepals. Eggs are never deposited in the blossoms.

RELATION OF QUALITY AND AMOUNT OF FOOD TO OVIPOSITION.

Eggs are never deposited in the older leaves and stems and but rarely in the fruit after it is two-thirds grown. The number of eggs deposited in a particular tree will depend exclusively upon the amount of new growth produced by that tree. It is impossible to induce the insects to oviposit in the tough leaves of potted orange trees, though hundreds have been confined upon such plants for many days. Eggs were deposited readily in the same kind of plants when one or more new leaves occurred there, even though only 20 to 25 insects were confined through one night only.

Oviposition does not occur in the minor food plants (including the Valencia orange, pomelo, lemon, pepper tree, Chinese umbrella tree, and grape), regardless of growth, in as great proportion to the number of infesting insects as in the Washington and Thompson's navel oranges.

RATE OF OVIPOSITION AND NUMBER OF EGGS DEPOSITED.

The preoviposition period in midsummer, when metabolism is rapid, is three or four days. The highest average daily rate of egg

deposition was secured in two experiments, in which the insects oviposited at the rate of 0.7 egg each per day. This is probably below the normal rate in the field in summer. The largest number of eggs occurring in the ovisac at one time and developed sufficiently to be observable with the ordinary powers of the microscope is five, and it is improbable that more than this number would develop and be deposited in one day. In 1911, of 1,050 female thrips collected monthly from April to October, inclusive, developed eggs were absent from 644, which may have oviposited just before captivity and were therefore not taken into account. In the remaining 406 insects there were 493 eggs, an average of 1.2 each. The percentage of thrips with only one egg visible was 80.7 per cent; with two eggs present, 17.1 per cent; and with more than two, but 2 per cent. It may be inferred from these data that on an average a single specimen will not deposit more than one egg per day, though the number will vary slightly with the character of the season and the quality and amount of food. Rarely as many as five may be deposited.

It would seem that in cool seasons such as 1911 the citrus thrips will deposit, on an average, only from 26 to 70 eggs in the course of her life, and this is believed to be one of the chief reasons for the relatively light infestation of thrips in that season as compared with such seasons as 1908 and 1909. In such exceptionally favorable seasons as the last mentioned it is possible that a large proportion of the insects might live the maximum of 49 days and deposit the maximum of 5 eggs each per day, making a total of 245 eggs for the individual.

DURATION OF THE LIFE CYCLE.

The duration of the life cycle was determined by two methods, viz, by the complete rearing of individual specimens through all the stages and by adding together the number of days in the egg, larval, and pupal stages. Owing to difficulties in handling only a comparatively small number of insects (13 to be exact) were carried through all the stages. From this record, obtained in May and early June, 1911, a maximum life cycle of 31 days, minimum of 28 days, and average of 29.8 days were secured. From the abundant data assembled in determining the duration of the separate immature stages the life cycle was found to be 33.9 days in May and early June and 29.1 days in September, months in which the weather was moderately cool; and in the period from June to September, during the hot weather, it was 15.2 days. The data are given in detail in Table VI. The figures do not take into account the three or four days between emergence and the first oviposition, which should be added for the complete life cycle.

TABLE VI.—*Duration of the life cycle of the citrus thrips, Lindsay, Cal., 1911.*

Period covered.	Average length of egg stage.	Average length of larval stage.	Average length of pupal stage.	Average duration of life-cycle.	Mean daily temperature.
	Days.	*Days.*	*Days.*	*Days.*	°*F.*
May 3 to June 9	18.8	8.2	6.9	33.9	62.67
June 2 to Sept. 5	7.3	4.4	3.5	15.2	76.03
Aug. 31 to Sept. 26	17.0	6.8	5.3	29.1	68.12

SEASONAL HISTORY.

About the middle of October the thrips begin to diminish noticeably and as the temperature goes lower, through November and December, they gradually disappear. Occasionally adult thrips will be found on the trees as late as December, from which it has been inferred that the winter is passed in this stage. As a matter of fact none of them lives through the month of January, and even the most painstaking search has never revealed a single specimen of larva, pupa, or adult later than January 5. Dead adults occur in increasing numbers on the leaves in October and November, corresponding with the period in which the living insects disappear most rapidly. It was determined by experiment, verifying field observations, that the winter is passed successfully in the egg stage only. Large numbers of adults and larvæ confined in the fall on orange plants, practically exposed to the prevailing weather except for being sheltered from rain, began to die early in November, very few larvæ pupating and these few dying as pupæ. All specimens were dead by December 26, but the eggs deposited produced larvæ the following spring.

The earliest time at which the citrus thrips have been found in the spring was March 25. There is, therefore, a period of from 8 to 11 weeks in January, February, and March in which feeding, oviposition, and all other activities of the insect cease, but which can not be called a hibernating period in the strict sense. The late issuing larvæ, as well as the pupæ and adults found in November and December, feed during the warm part of the day until the first severe frost kills them. The date of issuance of the first spring larvæ will depend upon the character of the season, coming early when the mean temperature for February and March is high and being delayed by a late cold spring.

MOVEMENTS OF THE THRIPS IN RELATION TO THE BLOSSOM AND GROWTH PERIODS OF THE WASHINGTON NAVEL ORANGE.

As the stems from which the first spring larvæ issue harden, the insects wander in search of better food and are soon found working up onto the new spring growth, which is usually 8 or 10 inches long by the time the larvæ have attained considerable numbers. Orange

growth and the appearance of thrips larvæ occur about 10 days earlier on the foothill slopes than on the valley level. Adult thrips begin to appear rapidly about the time the Washington navel trees are in full bloom, and the growth from 1 to 3 feet long, usually about the middle of April, and the resultant oviposition and feeding on the spring growth soon bring their injury into prominence. About the time one-third or more of the petals have fallen the first growth of foliage begins to harden and the thrips transfer to the little fruits. This period of transfer usually will fall between April 15 and May 30, depending upon conditions of growth and bloom.

The first injury to the fruit is caused largely by a comparatively few of the first larvæ which issue from it, feeding deeply in a circle about the stem, the injury so made eventually developing into the ring scars typical of citrus-thrips injury. Severe injury to the fruit begins as soon as the petals drop, increasing from that time until the oranges average about the size of a tennis ball. The more serious damage usually is done between the middle of April and the early part of July. Adult thrips then begin to leave the oranges, which become tough and distasteful to them, and transfer to the second growth of foliage. A few thrips feed and oviposit on the fruit practically throughout the season, however, and slight injury may often occur until the last of September. In 1911, the leaf growth was sparse and the amount of late injury to the fruit was unusual, being considerably greater than had been expected from the relative scarcity of thrips.

MIGRATION OF THRIPS TO SECONDARY FOOD PLANTS DUE TO SCARCITY OF ORANGE GROWTH.

The transfer of thrips from oranges to the secondary food plants takes place every season in greater or less degree, depending upon food conditions. The scarcity of suitable citrus food in 1911, approximately from June 30 to August 30, led to an unusual increase of the insects on certain other plants during that period. Grapes are especially subject to infestation at such times, and one case was reported to the writer in which both leaves and berries of a small vineyard were severely injured. During this period in which the thrips are scattered widely over their various food plants—roughly, during June, July, and August—reproductive activity is at its minimum.

CONGREGATION OF THRIPS ON LATE SUMMER GROWTH OF CITRUS.

Washington navel and Valencia orange trees in the San Joaquin Valley make from three to six successive new growths during the summer, depending on weather conditions, care of the grove, and age and health of the trees. In exceptionally favorable seasons there is

some new growth on the trees throughout the summer, but ordinarily there are two periods in which the growths are most attractive to thrips, one occurring in May and June, the other in August and September. During the August–September period the tissues of most of the deciduous food plants and the rind of the oranges are tough and distasteful, and there is a steady, often sudden, influx of thrips from scattered locations to the new foliage of the orange and some other citrus. The insects apparently become more numerous than ever, being more closely concentrated than at any other time of year.

In this period of the season, therefore, the following conditions favorable to the thrips progeny of the ensuing spring usually occur: The food supply is abundant and concentrated. The proportion of male thrips is increased, and mating and oviposition occur to a much greater extent than at any other time. This most favorable circumstance of abundant food in comparatively small space at just the time when the insect must produce the eggs for the next summer's generation is a principal factor in the rise of the species as a pest. It has been brought about by the occurrence in recent years of large numbers of vigorous young orange trees which the thrips was able to substitute for the miscellaneous weeds previously constituting its food supply.

GENERATIONS.

It is impossible to distinguish between generations of the citrus thrips, except perhaps the first and second summer generations, when growth is slow. Throughout the middle of the summer the life cycle occupies from 15 to 16 days, while oviposition covers from 25 to 30 days. Thus the complete life cycle may be passed by any given lot of individuals and eggs deposited by them to begin another generation while their progenitors are still ovipositing. This causes an overlapping of broods, such that it is impossible to distinguish between them. The number of generations will depend, of course, upon the character of the season. An early, warm spring followed by a prolonged, hot summer may result in the production of eight or more generations. In seasons such as 1911, six full generations may be expected between the middle of April and the first of November.

NATURAL CHECKS.

FREEZES.

Practically all sections of California where oranges are grown are subject to occasional freezes of varying severity, which always occur between November 15 and March 1, when the citrus thrips are practically all in the egg stage in the leaves and stems. The shoots most severely injured by freezes are those in which a majority of the eggs

are deposited, and thus it occasionally happens that a considerable number of the eggs are frozen. In the winter of 1911-12 more or less severe freezing occurred throughout the citrus-growing sections of the State. The leaves and stems of the principal summer's growth were browned and withered, and the thrips suffered a considerable reduction in numbers in many orchards. For example, an orchard which had been severely infested by thrips during the three years from 1909 to 1911, inclusive, and particularly in 1911, when the entire crop was rejected because of thrips scabbing, was frosted so badly during the winter of 1911–12 that the tender leaves and stems were wilted and blackened well down into the leaf expanse of the trees. In August, 1912, examination of the fruit from this orchard showed only 13 per cent of it to be marked by thrips, the degree of injury being noted at the time as mostly very slight stem-end rings. Thrips were very scarce and the leaves showed little injury except in scattered spots.

RAINS.

From the fact that rains are supposed to be a powerful agency in the natural control of some species of thrips, it has been argued that a season of unusually heavy rainfall would reduce greatly the number of citrus thrips. Whatever merit rainfall may have in checking thrips of other species, its effect on the citrus thrips under the conditions prevailing in the San Joaquin Valley and in Arizona could not be of the least importance, since the heavier rains do not begin there until October at the earliest, and usually not before November or December, by which time almost all the overwintering eggs have been deposited. In spring the rains cease before the thrips emerge in any considerable number. The season of 1909, following the heaviest rainfall in the three-year period from 1909 to 1911, inclusive, in the San Joaquin Valley, was the worst season for thrips injury on record.

NATURAL ENEMIES.

INSECTS.

The most important insect enemy of the citrus thrips is the larva of the common lacewing fly of California (*Chrysopa californica* Coq.).[1] In its early stages this larva feeds largely upon larvæ of the citrus thrips. In October, 1911, an examination of 10 one-year-old orange trees on which thrips were numerous disclosed an average of 25 eggs of this Chrysopa per tree. A number of the sickle-jawed larvæ were also present in the trees, and several of the smaller ones were engaged busily in feeding upon thrips. The thrips were indeed almost the only food available to the lacewings in quantity on these

[1] Identified by Nathan Banks.

trees. Adult thrips suffer from the lacewings only when the weather has become so cool as to make the thrips sluggish.

In its early larval stage, the lady beetle (*Hippodomia convergens* Guér.) feeds upon the citrus thrips. Although this Coccinellid is extremely numerous throughout the Tulare County citrus belt, it feeds mostly upon aphids and other larger insects which occur on orange trees and more particularly on truck crops, and is of no great importance in destroying the thrips.

A thysanopteron enemy of the citrus thrips which seemed to be increasingly important in 1912 was the 6-spotted thrips (*Scolothrips sexmaculatus* Perg.). The principal food of the 6-spotted thrips, however, appears to be mites which occur mainly on plants other than citrus in Tulare County and which are not numerous enough on orange to attract large numbers of the predatory thrips. This thrips is apparently just learning the possibilities of abundant food offered by the citrus thrips, and perhaps will feed more extensively upon it as time goes on. It is apparently unable to catch the adults and therefore feeds only upon the larvæ.

The younger nymphs of one of the assassin bugs (*Zelus renardii* Kolen)[1] are fairly common upon orange trees in Tulare County and have several times been seen feeding upon larvæ of the citrus thrips. The more advanced assassin bugs, however, feed principally upon larger, and often harmless, insects and it is only in their first and early second instars that they attack thrips.

The small reddish nymph of the plant bug (*Triphleps insidiosus* Say) has occasionally been seen feeding upon flower thrips in orange and several other blossoms. When imprisoned with *Scirtothrips citri* it flourished very well upon the latter, but when the flower thrips (*Frankliniella tritici* Fitch.) was also placed in the bottle the latter proved more attractive to the insect, doubtless because of its larger size and greater sluggishness of movement. *Triphleps insidiosus* has not been seen upon orange trees after the blossom period, when the flower thrips, upon which they mostly feed, have left the trees.

INTERNAL PARASITES.

Thus far no internal parasites have been found attacking the citrus thrips. Although the Chalcid parasite of Thysanoptera (*Thripoctenus russelli* Crawf.)[2] has been found by the writer in the San Joaquin Valley affecting the bean thrips (*Heliothrips fasciatus* Perg.) and the flower thrips (*Frankliniella tritici* Fitch.), for some

[1] Identified by Otto Heideman.

[2] This parasite was first reared from *Heliothrips fasciatus* Perg. by H. M. Russell (see U. S. Dept. Agr., Bur. Ent., Tech. Ser. Bul. 23, pt. 2, Apr. 27, 1912). It was described as a new genus and species by J. C. Crawford in 1911 (see Proc. Ent. Soc. Wash., vol. 13, p. 233, 1911).

reason it does not attack the citrus thrips, although the close association of this thrips with the bean thrips on orange trees seems to be a good reason why it should do so, and it is quite possible, seemingly, that the citrus thrips may in the future become one of its hosts.

SPIDERS.

A large number of spiders, representing three or four families, capture the citrus thrips as a part of their food. The most important of these in the matter of destroying citrus thrips is a small gray spider belonging to the family Dictynidae, genus Dictynus.[1] The Dictynidæ are tubeweavers, and this particular species commonly spins a thin sheet of web irregularly across an orange leaf, in a single one of which adult and larval citrus thrips have often been counted to the number of 50 or more. It is rare to find a web of one of these young spiders with less than from 5 to 10 thrips entangled in its meshes. The little spiders have several times been seen with the thrips in their jaws.

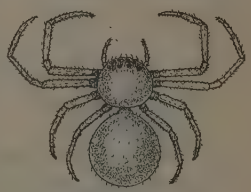


FIG. 9.—Young spider, *Misumessus* sp., which preys upon the citrus thrips. (Original.)

The second most important Arachnid enemy of the citrus thrips is one of the jumping spiders (Fam. Salticidae), known as *Thiodina puerperis*. This spider is very active in seizing its prey, which it pounces upon cat fashion. From 4 to 10 or more thrips will be eaten in succession by one of these young spiders. The spider drains the juice from the body of its victim and casts the skeleton aside.

Another spider (fig. 9), belonging to the genus Misumessus, has often been taken in its immature stages with the citrus thrips in its possession. This spider is a yellowish, very active creature belonging to the family of so-called crab spiders (Thomisidae). It is commonly found, solitary, upon orange leaves. It does not spin a web.

A small black spider (*Erigone* sp.), less common on orange trees than any of the foregoing, is sometimes seen with adult citrus thrips in its possession. As is the case with all the foregoing thrips enemies, insects and spiders alike, except the 6-spotted thrips, this spider feeds upon thrips when it is young, but confines itself mostly to larger insects after it has become mature. The young, actually about one-twentieth inch long, is shown greatly magnified in figure 10.

FUNGUS GROWTH ATTACKING THRIPS.

The spores of an unidentified fungus have occasionally been seen about the bodies of citrus thrips which have died in captivity, but it seems probable that either this fungus attached the insects after

[1] All spiders referred to herein have been identified by Nathan Banks.

death or the attack resulted from the excessive moisture formed in the rearing jar by the orange leaves. It results only from abnormal conditions and is plainly unimportant in the field.

IMPORTANCE OF NATURAL AGENCIES IN CONTROLLING THE THRIPS.

The citrus thrips appears to be subject to controlling influences the nature of which is difficult to determine completely. The most severe infestation recorded against the insect occurred in Tulare County in 1909, when 90 per cent of the entire crop of navel oranges of that county was thrips marked, and close to 20 per cent of it was so badly scarred and distorted that it was unsalable at a profitable price. In 1910 the insects failed to appear in anything like their numbers of 1909 and the injury was less than 50 per cent of what it had been during that season. This naturally affected the results due to spraying by the growers in 1910, even where the work was done thoroughly, as in many cases unsprayed fruit was injured so slightly that the difference in returns between sprayed and unsprayed fruit was so small that very little profit was derived from the operation. In 1911, thrips were still less numerous and more scattered early in the season and it looked as though the injury would be very slight. Owing, however, to an unusually backward season, in which the trees made but slow and scanty growth, the insects were forced to depend to a greater extent than usual on the fruit for food, on which they concentrated in the latter part of the season. The marking was late in appearing, but at the end of the season proved to be somewhat more extensive than in 1910. This illustrates the fact that the abundance of thrips is not always a reliable index of the extent of expected damage to the fruit.

FIG. 10.—Immature spider, *Erigone* sp., which preys largely upon the citrus thrips. (Original.)

The chief factors influencing the decrease of thrips subsequent to 1909 are undoubtedly the climatic changes and relative inadequacy of the food supply. In 1910 and 1911 the late, cold spring was the cause of the slowness with which the insects increased during April, May, and June; while the same climatic condition, in retarding the growth of the trees, further checked the increase of the insects by reducing their food. Furthermore, it forced the insects to scatter widely over many food plants, thus hindering reproduction and greatly retarding oviposition by causing dearth of suitable plant tissue.

CONTROL EXPERIMENTS.

PLAN OF SPRAYING EXPERIMENTS IN 1911.

The principal experiments in 1911 were conducted in an orange orchard about 2 miles east of Lindsay, Cal., and about the same distance from the nearest foothills, lying between the latter and the town. A supplementary set of experiments was conducted in an orchard situated on the slope of the foothills about 2 miles from the first orchard, the object being to test out practically the same sprays under different conditions. The trees of the latter orchard were younger than those of the former, and, as is true of most foothill groves, worse thrips infested. The insecticides used in the two sets of experiments are listed below, Series I referring to the valley orchard and Series II to the foothills orchard. A further experiment, in which 2,550 Valencia and Joppa and a number of navel nursery trees were sprayed, was conducted in a third orchard about 2 miles from the foothills.

Series I: Valley ranch.

Plat No. 1. Unsprayed, check.
2. Lime-sulphur solution (36° Baumé), 1–28.
3. Lime-sulphur solution (36° Baumé), 1–56.
4. Unsprayed, check.
5. Tobacco extract (40 per cent nicotine sulphate), 1–800.
6. Tobacco extract (40 per cent nicotine sulphate), 1–1,600.
7. Unsprayed, check
8. Lime-sulphur solution (36° Baumé), 1–86, and tobacco extract (40 per cent nicotine sulphate), 1–800.
9. Lime-sulphur solution (36° Baumé), 1–86, and tobacco extract (40 per cent nicotine sulphate), 1–1,600.
10. Lime-sulphur solution (36° Baumé), 1–86, and tobacco extract (40 per cent nicotine sulphate), 1–2,400.
11. Cresol soap, 1–500, and tobacco extract (40 per cent nicotine sulphate), 1–800.
12. Cresol soap, 1–500, and tobacco extract (40 per cent nicotine sulphate), 1–1,600.
13. Unsprayed, check.
14. Fish-oil soap, 1–250, and tobacco extract (40 per cent nicotine sulphate), 1–800.
15. Fish-oil soap, 1–250, and tobacco extract (40 per cent nicotine sulphate), 1–1,600.
16. Sulphur-soda solution,[1] 1–25.

[1] The sulphur-soda solution (plats 16 and 17) was prepared as follows:

Powdered sulphur	pounds	30
Powdered caustic soda (98 per cent)	do	15
Water to make	gallons	30

The sulphur was made into a paste with water and the soda added, while the mixture was constantly stirred, in sufficient quantity to cause boiling, a little water being added occasionally to retard the cooking. When all the sulphur was dissolved, enough cold water was added to make a stock solution of 30 gallons. A clear, amber liquid, much resembling good lime-sulphur, was the result.

Plat No. 17. Sulphur-soda solution, 2–25.
18. Resin wash,[1] 1–3.
19. Resin wash, 1–5.
20. Resin wash, 1–10.
21. Plain water.
22. Unsprayed, check.

Each of the foregoing plats of Series I consisted of two rows of 25 trees each, or 50 trees to the plat. The trees were 18-year-old Washington navels, and the entire experimental block was bordered on two sides by trees of the same kind and planting, and on the remaining sides by Valencias and a road, respectively.

Series II: Foothills ranch.

Plat No. 1. Lime-sulphur solution (33° Baumé), 1–75, and tobacco extract (2¾ per cent nicotine sulphate), 1–150.
2. Lime-sulphur solution (33° Baumé), 1–75, and tobacco extract (2¾ per cent nicotine sulphate), 1–100.
3. Tobacco extract (2¾ per cent nicotine sulphate), 1–100.
4. Tobacco extract (40 per cent nicotine sulphate), 1–1,600.
5. Tobacco extract (40 per cent nicotine sulphate), 1–2,400.
6. Tobacco extract (40 per cent nicotine sulphate), 1–1,600, and cresol soap, 1–400.
7. Tobacco extract (40 per cent nicotine sulphate), 1–2,400, and cresol soap, 1–400.
8. Plain water.
9. Unsprayed, check.
10. Tobacco extract (40 per cent nicotine sulphate), 1–800.
11. Tobacco extract (40 per cent nicotine sulphate), 1–1,600, and fish-oil soap, 1–200.
12. Tobacco extract (40 per cent nicotine sulphate), 1–2,400, and fish-oil soap, 1–200.

Plats 1 to 8 of Series II consisted of 4 rows of 28 trees each; plat 9, of 5 rows of 28 trees; the remaining plats, of 2 rows of 28 trees each. All trees were 4-year-old Washington navels. The only lime-sulphur available for use unmixed in Series II was a quantity which had been exposed to the air for a year. It was used, with misgivings, and the results, which are omitted as of no value, proved conclusively that it had lost most of its insecticidal power.

[1] The stock resin wash (plats 18, 19, and 20) was made fresh for each application, as follows:

Resin	pounds	20.0
Caustic soda (98 per cent)	do	3.6
Fish oil	pints	3.0
Water enough to make	gallons	50.0

All the ingredients were placed in a 60-gallon iron kettle with 10 or 15 gallons of water and brought to boiling. Melting was aided by constant stirring. Hot water was added occasionally until the mixture had boiled constantly for about 1½ hours and had reached 50 gallons.

NURSERY-SPRAYING EXPERIMENTS.

Plat No. 1. 2,550 Valencia and Joppa orange trees, sprayed with lime-sulphur, 1–50.

2. Several thousand Washington navel orange trees, sprayed with lime-sulphur, 1–75, and tobacco extract (2¾ per cent nicotine sulphate), 1–150.

Time and number of applications.—Three applications of the insecticides were made at the valley ranch, Series I, with the object of saving the fruit from injury. Owing to a very cold and backward season and the age of the trees, growth was scant and the first application was not necessary until June 2. The second application was timed principally to catch adult thrips which had transferred to the fruit and larvæ which had issued from it since the first application and was started June 17. The third application was timed solely by the abundance of thrips on the fruit and was begun July 8.

The first application at the foothills ranch, Series II, was started May 15, and the second June 6, both about a week later than was intended, owing to failure of the ranch foreman to produce sprayer, teams, and labor promptly when requested, the writer being dependent upon the grower for these items by agreement. The difference in the time of the first application between the valley ranch, Series I, and the foothills ranch, Series II, indicates approximately the difference between the two localities in the time when the petals dropped and the thrips began to feed on the fruit.

The nursery trees were sprayed June 7, July 15, and August 31; the sprayings were timed solely by the abundance of thrips.

RESULTS FROM SPRAYING.

The determination of the relative value of the different insecticides and of spraying is based solely upon the effectiveness of the work in raising the commercial grade of the fruit. These grades represent money values, and their improvement, which was the primary object of the investigation, thus effects a tangible saving. The qualities determining the grading of oranges were studied out at the various packing houses, and in this work the writer received the willing cooperation of the managers of most of the packing houses at Lindsay, Cal. As the fruit from the experiments of Series I was graded under a different system from that of Series II, it will be necessary to state the results of each series of experiments in terms of the commercial grading of the fruit from that series.

RESULTS IN SERIES I.

The results of the spraying experiments at the valley ranch are summarized in Tables VII and VIII. The comparatively slight infestation in this orchard in 1911 is evident from the figures for the unsprayed plats, Nos. 1, 4, 7, 13, and 22, in Table VII. The variation in the percentage of fruit injured sufficiently to reduce the grade

in the different check plats shows the uncertainty of the infestation and the necessity, in order to obtain reliable comparison, of several interspersed lots of unsprayed trees. The comparisons would be still more accurate if it had been feasible to leave single untreated trees interspersed among the sprayed trees of each plat, but the work of keeping the fruit from a large number of scattered trees in 17 plats separate for examination would involve too much time and expense, and there would be much risk of the pickers, paid by the box, mixing the fruit.

TABLE VII.—*Comparison of fruit sprayed for the citrus thrips with that unsprayed, Series I, Lindsay, Cal., 1911.*

No. of plat.	Treatment of trees.	Amount of fruit examined.		Commercial grading of fruit.			
		Number of loose boxes.	Number of oranges.	Number of first-grade oranges.	Number of second-grade oranges.	Per cent first-grade oranges.	Per cent second-grade oranges.
1	Untreated	20	2,386	1,981	405	83.1	16.8
2	Lime-sulphur (36° Baumé), 1–28	20	2,308	2,285	23	98.9	1
3	Lime-sulphur (36° Baumé), 1–56	20	2,243	2,225	18	99.1	.8
4	Untreated	20	2,180	1,734	446	79.4	20.4
5	Tobacco extract (40 per cent nicotine sulphate), 1–800	20	2,300	2,247	53	97.5	2.3
6	Tobacco extract (40 per cent nicotine sulphate), 1–1,600	20	2,281	2,160	121	94.6	5.1
7	Untreated	20	2,442	2,188	254	89.5	10.4
8	Lime-sulphur (36° Baumé), 1–86, and tobacco extract (40 per cent nicotine sulphate), 1–800	20	2,337	2,272	65	97.1	2.7
9	Lime-sulphur (36° Baumé), 1–86, and tobacco extract (40 per cent nicotine sulphate), 1–1,600	20	2,420	2,321	99	95.8	4
10	Lime-sulphur (36° Baumé), 1–86, and tobacco extract (40 per cent nicotine sulphate), 1–2,400	20	2,387	2,174	213	91	8.8
11	Cresol soap, 1–500, and tobacco extract, 1–1,600	20	2,345	2,071	274	88.2	11.6
12	Cresol soap, 1–500, and tobacco extract (40 per cent nicotine sulphate), 1—2,400	20	2,126	1,740	386	81.8	18.1
13	Untreated	20	2,648	1,878	770	70.8	29
14	Fish-oil soap, 1–250, and tobacco extract (40 per cent nicotine sulphate), 1–800	20	2,555	2,299	256	89.8	10
15	Fish-oil soap, 1–250, and tobacco extract (40 per cent nicotine sulphate), 1–1,600	20	2,444	2,041	403	83.4	16.4
16	Sulphur-soda, 1–25	20	2,563	2,294	269	89.4	10.4
17	Sulphur-soda, 2–25	20	2,622	2,510	112	95.7	4.1
18	Resin wash, 1–3	20	2,700	(1)	(1)	(1)	(1)
19	Resin wash, 1–5	20	2,760	(2)	(2)	(2)	(2)
20	Resin wash, 1–10	20	2,596	(3)	(3)	(3)	(3)
21	Plain water	20	2,639	2,191	448	82.9	16.9
22	Untreated	20	2,650	2,176	474	82	17.8

[1] 83.6 per cent of fruit injured by spray.
[2] 69.6 per cent of fruit injured by spray.
[3] 43.7 per cent of fruit injured by spray.

The fruit from plats 1 and 4 was considered as one unsprayed lot for comparison with the sprayed fruit from plats 2 and 3; that from plats 4 and 7 as a check on the same from plats 5 and 6, etc., in order to get unsprayed fruit as nearly as possible representative of what sprayed fruit would have been without treatment. More than

95 per cent of the grade reduction occurring in the orchard was caused by thrips injury. The efficacy of the various insecticides in raising the grade of the fruit is shown in Table VIII.

TABLE VIII.—*Efficacy of the spray mixtures in Series I.*

Unsprayed fruit.			Sprayed fruit.			Grade-raising efficacy of the sprays.
Plat No.	Number of boxes first-grade fruit.	Number of boxes low-grade fruit.	Plat No.	Number of boxes first-grade fruit.	Number of boxes low-grade fruit.	
						Per cent.
1 and 4.	81	19	2	99	1	95
			3	99	1	95
4 and 7.	85	15	5	98	2	87
			6	95	5	67
7and 13.	80	20	8	97	3	85
			9	96	4	80
			10	91	9	55
			11	88	12	40
			12	82	18	10
13 and 22.	79	21	14	90	10	52
			15	84	16	24
			16	90	10	52
			17	96	4	81
			21	83	17	19

The relative worth of the spray mixtures in Series I, as indicated in Tables VII and VIII, may be summarized as follows:

1. From 80 to 90 per cent grade-reducing injury prevented by—
   Lime-sulphur (36° Baumé), 1–28.
   Lime-sulphur (36° Baumé), 1–56.
   Tobacco extract (nicotine sulphate 40 per cent), 1–800.
   Lime-sulphur (36° Baumé), 1–86, and tobacco extract (40 per cent nicotine sulphate), 1–800 and 1–1,600.
   Sulphur-soda solution, 2–25.
2. Between 60 and 80 per cent of injury prevented by—
   Tobacco extract (40 per cent nicotine sulphate), 1–1,600.
3. From 50 to 60 per cent of injury prevented by—
   Lime-sulphur (36° Baumé), 1–86, and tobacco extract (40 per cent nicotine sulphate), 1–2,400.
   Fish-oil soap, 1–250, and tobacco extract (40 per cent nicotine sulphate), 1–800.
   Sulphur-soda solution, 1–25.
4. Less than 50 per cent of injury prevented by—
   Cresol soap, 1–500, and tobacco extract (40 per cent nicotine sulphate), 1–1,600.
   Fish-oil soap, 1–500, and tobacco extract (40 per cent nicotine sulphate), 1–2,400.
   Fish oil soap, 1–250, and tobacco extract (40 per cent nicotine sulphate), 1–1,600.
   Plain water.
5. Fruit and leaves severely injured by—
   Resin wash, 1–3; 1–5; and 1–10.

Contrary to expectation, the addition of soaps to tobacco solutions did not appear to increase their efficacy, but, on the contrary, seemed to lower it. Straight tobacco extract with 40 per cent nicotine sulphate,

diluted 1–800 and 1–1,600, respectively, gave better results than at the same strengths with the addition of soaps. This fact is difficult to account for, but may be due partly to more severe infestation of the trees on which the soap was used than on those sprayed with the unmodified tobacco extracts. The soap plats were located two on either side of check plat 13, in which there was 29 per cent of low-grade fruit; but the comparison is made with the average between plats 13 and 22, in which there was 21 per cent low-grade fruit. The infestation may have been as severe in the soap plats as in check plat 13. The plats treated with straight tobacco extracts lay between check plats 4 and 7, with only 20 and 5 per cent low-grade fruit, respectively. The foregoing explanation does not hold, however, for the similar results from soap and tobacco extracts, under different conditions, in Series II, and the latter experiments seem to lend further weight to the probability that but little benefit will result from adding soaps to tobacco extracts as sprays for the citrus thrips. Experiments under very heavy and uniform thrips infestation, however, might result somewhat differently.

RESULTS IN SERIES II.

The fruit from the experimental plats in Series II was packed in three commercial grades instead of two, as was that of Series I. The results from spraying are given in percentage of fruit of each of the three grades, from all the separate plats, in Table IX.

TABLE IX.—*Comparison of fruit sprayed for the citrus thrips with that unsprayed, Series II, Lindsay, Cal., 1911.*

Plat No.	Treatment of trees.	Amount of fruit examined.		Commercial grading of fruit.		
		Number of boxes.	Number of oranges.	Per cent first-grade fruit.	Per cent second-grade fruit.	Per cent third-grade fruit.
1	Lime-sulphur (33° Baumé), 1–75, and tobacco extract (2¾ per cent nicotine sulphate), 1–150	20	2,492	40.3	51.8	7.8
2	Lime-sulphur (33° Baumé), 1–75, and tobacco extract (2¾ per cent nicotine sulphate), 1–100	20	2,504	46	44.4	9.4
3	Tobacco extract (2¾ per cent nicotine sulphate), 1–100	20	2,371	25.7	53.1	21
4	Tobacco extract (40 per cent nicotine sulphate), 1–1,600	20	2,502	33	46.6	20.2
5	Tobacco extract (40 per cent nicotine sulphate), 1–2,400	20	2,711	19.2	54	26.7
6	Cresol soap, 1–400, and tobacco extract (40 per cent nicotine sulphate), 1–1,600	20	2,336	30.2	48.3	21.3
7	Cresol soap, 1–400, and tobacco extract, 1–2,400	20	2,403	22.2	52.8	24.7
8	Plain water	20	2,582	7.4	45.7	45.7
9	Untreated	20	2,271	6.7	52	41.1
10	Tobacco extract (40 per cent nicotine sulphate), 1–800	20	2,176	42	47.6	10.2
11	Fish-oil soap, 1–200, and tobacco extract, (40 per cent nicotine sulphate), 1–1,600	20	2,147	30	51.3	18.6
12	Fish-oil soap, 1–200, and tobacco extract, (40 per cent nicotine sulphate), 1–2,400	20	2,049	27.4	50.7	21.8

The relative worth of the spray mixtures in this series may be divided roughly into four groups, according to their relative merits, as follows:

1. Sprays raising about three-fourths of the injured fruit from third to first grade:
   - Lime-sulphur (33° Baumé), 1–75, and tobacco extract (2¾ per cent nicotine sulphate), 1–150.
   - Lime-sulphur (33° Baumé), 1–75, and tobacco extract (2¾ per cent nicotine sulphate), 1–100.
   - Tobacco extract (40 per cent nicotine sulphate, 1–800.
2. Sprays raising about one-half the injured fruit from third to first grade:
   - Tobacco extract (2¾ per cent nicotine sulphate), 1–100.
   - Tobacco extract (40 per cent nicotine sulphate), 1–1,600.
   - Cresol soap, 1–400, and tobacco extract (40 per cent nicotine sulphate), 1–1,600.
   - Fish-oil soap, 1–200, and tobacco extract (40 per cent nicotine sulphate), 1–1,600.
   - Fish-oil soap, 1–200, and tobacco extract (40 per cent nicotine sulphate), 1–2,400.
3. Sprays raising about one-third of the injured fruit from third to first grade:
   - Tobacco extract (40 per cent nicotine sulphate), 1–2,400.
   - Cresol soap, 1–400, and tobacco extract (40 per cent nicotine sulphate), 1–2,400.
4. Without insecticidal value:
   - Plain water at high pressure.

As indicated by the figures in Table IX, insecticides in the first of the foregoing groups raised from 31 to 33 per cent out of a probable 41 per cent of third-grade fruit to first grade; i. e., over three-fourths of it; those in the second group, only about 20 per cent, or about half of it; and those in the third group prevented only about one-third of the injury.

The results from the more effective sprays in Series II may be stated in terms of the gross receipts of the fruit. The difference in price per box between the grades for this particular fruit was as follows: First-grade fruit brought 67 cents more per box than third-grade and 29 cents more than second grade, which brought 38 cents more than third-grade fruit. The differences in receipts per hundred boxes between sprayed plats 1, 2, and 10 and the check plat are given below:

Plat 1.—33.3 boxes raised from third grade to first grade, at 67 cents	$22.31
0.2 boxes raised from second grade to first grade, at 29 cents	.06
Amount received per 100 boxes sprayed fruit in excess of the unsprayed	22.37
Plat 2.—31.7 boxes raised from third grade to first grade, at 67 cents	21.23
7.6 boxes raised from second grade to first grade, at 29 cents	2.20
Amount received per 100 boxes sprayed fruit in excess of unsprayed	23.43

Plat 10.—30.9 boxes raised from third grade to first grade, at 67 cents	$20.70
4.4 boxes raised from second grade to first grade, at 29 cents per box	1.27
Amount received per 100 boxes sprayed fruit in excess of unsprayed	21.97

Taking into consideration the fact that only two early applications were made in Series II, at the foothills ranch, it will be seen that in seasons like 1911, when the infestations are light, reasonably successful commercial spraying may be depended upon to insure an increase of at least 25 cents for every box of sprayed fruit over the unsprayed fruit.

RESULTS IN NURSERY SPRAYING EXPERIMENTS.

That portion of the nursery designated as Plat 1 was sprayed thoroughly with a gasoline-power outfit used in orchard work. The trees in Plat 2 were given equally careful treatment, being well drenched each time, but the spraying was done with a small, hand-power outfit, fitted with a nozzle of the Vermorel type. The results from the use of the gasoline-power outfit were greatly superior to those from the hand-power outfit, demonstrating the greater efficiency of the former. In October the trees sprayed with the gas-engine outfit looked so remarkably clean and vigorous that they attracted attention; at this time they had a good growth of about 3 feet, without curled leaves and with but little of the whitish discoloration characteristic of thrips injury to leaves. On the trees sprayed with the hand-power outfit the proportionate growth was somewhat less and thrips marking was noticeably more severe.

CONCLUSIONS FROM SPRAYING TESTS.

In the foregoing two sets of tests the following insecticides and combinations gave the best results. Any of these mixtures may be relied upon to give satisfactory control when properly applied.

1. *Lime-sulphur solution.*—If the lime-sulphur is of a density of 36° Baumé, dilute 1 gallon with 56 gallons of water; if of a density of 33° Baumé, dilute 1 gallon with 50 gallons of water.

2. *Sulphur-soda solution.*—Two gallons of the stock solution, prepared as described on page 29, diluted with 25 gallons of water.

3. *Lime-sulphur and tobacco extract (40 per cent nicotine sulphate).*—Dilute 1 part of the lime-sulphur, if 34 to 36° Baumé, with 86 parts of water; if 30 to 33° Baumé, with 75 parts of water. Then add 1 part of the tobacco extract to 1,000 parts of the lime-sulphur as diluted above.

4. *Tobacco extract (40 per cent nicotine sulphate).*—Dilute 1 part with 800 parts of water.

Lime-sulphur and soda-sulphur solutions are more effective against the citrus thrips than any other mixture thus far tested, and particularly the lime-sulphur at the strength stated above. A large per-

centage of the thrips can be killed by spraying with this solution, and there is a further effectiveness due to its decomposition for a long period after deposition on the leaves. In orchards sprayed with good lime-sulphur the sulphurous odor is often strong for two months or more after the applications. The decomposition products repel the thrips, which are slower to reinfest orchards so sprayed than those sprayed with solutions that soon evaporate and leave no trace.

Tobacco extracts when used at the proper strengths are also very effective. Both tobacco extract and lime-sulphur, when mixed together, are effective in weaker solutions than when diluted with water alone. Contrary to expectation, the addition of soaps to tobacco extract did not give increased value to the tobacco in these tests. Soap solutions used alone appear to be worthless at the dilutions tested.

Resin wash at any strength practicable for use on the orange trees in this section is worthless. At the greatest strength used in these experiments it failed to reduce thrips injury to an extent worthy of attention. It is, furthermore, very injurious to fruit and foliage.

Plain water spraying was utterly ineffective, demonstrating that merely striking the thrips with a liquid at high pressure to wash them from the trees has no appreciable effect in diminishing their numbers. A few hours after spraying with water there remained on the trees as many living, active thrips as before spraying.

INJURIES TO CITRUS RESULTING FROM SPRAYING.

INJURY FROM DISTILLATE-OIL EMULSION.

In experiments conducted in 1910, emulsions containing 2 per cent of distillate oil caused severe staining to ripe oranges. Dark streaks were formed on the rind where the liquid had collected in drops and run down. A patent spray emulsion caused more staining than the home product at the same strength.

INJURY FROM RESIN WASH.

On July 20, 1911, about two weeks after the final spray application, injury appeared from the resin wash in plat 18, Series I. About 3 per cent of the leaves had turned brown and fallen and most of the oranges had become spotted with the varnish. In some cases the varnish had collected in drops and run down over the surface, finally drying to a hard, gummy substance. By September 25 the injury apparently had reached its highest degree and was serious in all three plats, though noticeably decreasing with the greater dilution of the wash. The epidermal cells of fruit protected from the direct rays of the sun were killed and a shallow, brown scab was formed. This scab often peeled off, leaving a film of light gray-green tissue

beneath. Where the liquid collected in large drops it formed a thick amber to black scab which did not slough off readily. The injury was most severe in places previously injured by thrips.

INJURY FROM LIME-SULPHER.

A small percentage of the fruit sprayed with lime-sulphur mixture diluted 1–28 (Series I, plat 2) developed in the rind slight hardened depressions resembling burns or scalds. Such injury occurred largely in spots previously injured by thrips, and in one case in a katydid scar. Less than 2 per cent of the fruit was spray-injured even by this strength of solution. In plat 3 (lime-sulphur 1–56) not more than one-half of 1 per cent of the exposed fruit was slightly injured in similar fashion.

In a special test on four orange trees, using lime-sulphur at the rate of 1 gallon to 15 gallons water and making the applications on the hottest days of the summer, very severe injury developed. By the first of June some of the fruit developed severe blisters, or hard, puffy, excrescences of the rind, and a small amount of the fruit fell to the ground. Unlike the injury from resin wash, that from the strong lime-sulphur soon attained its severest degree and was always most severe on oranges exposed to the direct rays of the sun, particularly the afternoon sun. It was also particularly severe in places where the fruit had been bruised or where it had been injured by insects. By fall, from 18 to 25 per cent of the fruit had developed spray injury, the average for all four trees being 21 per cent.

Lime-sulphur is harmless to fruit or leaves when used weaker than 1 part to 28 parts water. It has a remarkably stimulating effect upon the leaf growth of orange trees. In all plats where lime-sulphur was used, no matter what the dilution, the trees sprayed with it produced a growth of foliage much in excess of that produced by their unsprayed neighbors.

SUMMARY OF RECOMMENDATIONS FOR CONTROLLING THE CITRUS THRIPS.

SPRAY MIXTURE AND TIME OF APPLICATION.

Plain lime-sulphur solution, 1 to 56 of the 36° Baumé density or 1 to 50 of the 33° Baumé, is recommended as the most reliable of the four best mixtures resulting from the tests.

The thrips first occur in injurious numbers at the same time that the navel orange blossoms drop most of their petals; they transfer from the leaves to the fruit gradually as the petals fall. The first spray application therefore should be made when four-fifths or more of the petals have fallen. This will check the thrips at a time when the orange is most susceptible of deep injury. The exact date for the application can not be given, as the period when the petals fall and the thrips transfer to the fruit will be as much as 30 days later in some seasons than in others, depending on the spring weather.

The second application should be timed to prevent injury both from larvæ issuing from the very young fruits and from adults emerging from the pupal stage existent at the time of the first application. This renewed attack may be expected to reach the danger point in from 10 to 14 days after the first spraying. The second spraying should not be delayed too long, as comparatively few larvæ may, by constantly feeding in a circle about the base of the fruit, cause deep ring scarring. Special effort should be made to drench only the fruit and the remaining tender leaves.

The third application may be delayed longer if the first two have been thorough and well timed. It generally takes the insects from three to four weeks to become dangerously numerous again, as they reinfest the sprayed trees much more slowly after the second spraying.

All three applications should be completed by the time the fruit is half grown, after which it rapidly loses its attractiveness for the insects, which then find it necessary to spread out over the comparatively scant tender orange growth and miscellaneous food plants.

During the latter part of August and early in September there is usually another abundant growth of orange shoots, and upon this the thrips congregate in large numbers. A fourth application during this period is advisable in some seasons to prevent severe injury to this growth, which is often the most abundant of the season.

The first spray application to nursery stock should be made when thrips become numerous on the spring growth and before their injury becomes very evident, usually between April 15 and May 15. In the case of trees budded in the fall the shoots springing from the original stock should be cut back the following spring as soon as the bud has attained a good growth. All the prunings should be burned to destroy contained eggs and larvæ. In Tulare County this pruning and burning usually can be accomplished during April. The growing scions must then be watched closely and as soon as thrips occur in numbers spraying should begin. From two to four further applications should follow the first spraying, depending upon the number of growths and the degree of infestation.

SUGGESTIONS FOR SPRAYING.

The gasoline-power outfit, by reason of its large nozzle capacity, reliability, and comparatively low cost of operation, is recommended for spraying bearing orchards, young orchards in excess of 10 acres, and large nurseries. Hand-power outfits, when of a type capable of maintaining a pressure of not less than 125 pounds, are suitable for spraying seed-bed and nursery stock and young orchards of small acreage.

The spraying outfit should be in perfect running order not later than April 1, with the insecticide materials at hand and conveniently

located near the water supply and as near as possible to the trees to be sprayed. Supplies should be ordered not later than the January or February preceding the spraying operations.

HOW TO SPRAY BEARING ORCHARDS.

It is best to use only two 50-foot leads of hose on a power outfit, with 10-foot rods each fitted with a Y which is angled to handle two nozzles. The latter should be of the larger chamber type, with disks bored to one-sixteenth inch. Each rodman should begin at about the middle of a tree, on the side away from the sprayer, and work around the tree until he reaches the starting point; he should then switch to the same point on the next tree without shutting off the nozzles and with as much economy of movement as possible.

The nozzles should be held about 2 feet from the tree so that the broad portion of the stream plays upon fruit and leaves. The trees should be swept from tip to base, special attention being given to the fruit and the tender growth, where the insects congregate. The pressure, if maintained at 150 to 200 pounds, will turn the leaves and whirl the little fruits so that all sides will be sprayed.

No attempt should be made to spray too many trees with a single outfit, and an application once commenced should be completed within 10 days. Nursery and young orchard trees will require from ½ gallon to 2 gallons of the dilute spray each; those from 5 to 10 years old should be given not less than 5 gallons each; and those from 12 to 18 years old not less than 8 gallons each.

HOW TO SPRAY NURSERIES AND YOUNG TREES.

For large nurseries the gas-engine outfit, where it can be advantageously used, is preferable to the hand outfit. Two 25-foot or even 15-foot leads of hose and 12-foot spray rods are generally most convenient for this work, though the equipment of hose and rods recommended for orchard work will answer very well. The excess hose length should be coiled over a peg fastened to the spray tank or engine hood, so that the young trees will not be injured by the dragging hose. In setting out a nursery it is preferable to leave driveways wide enough to accommodate sprayer and team at intervals of eight rows (where the rows are 4 feet apart) throughout the length of the bed; for example, one between the fourth and fifth rows, and again between the twelfth and thirteenth, etc. Eight rows of trees, four either side of the driveway, may then be reached each trip, using 12-foot spray rods; eight more rows may be taken on the return trip, etc. Either the large chamber type or the single Bordeaux nozzles may be used to good advantage, but the delivery of the spray need not be so rapid as for orchard work. The trees will need attention only when the growth is tender.

BIBLIOGRAPHY.

(1) Coit, J. E.
1908. Citrus culture in the arid Southwest. *In* Univ. Ariz. Agr. Exp. Sta. Bul. 58, p. 289–328, 9 fig.
Pages 319–320: *Euthrips occidentalis.*

(2) Moulton, Dudley.
1909. The orange thrips. U. S. Dept. Agr. Bur. Ent. Tech. Ser. 12, pt. 7, p. 119–122, pl. 8.

(3) Morrill, A. W.
1909. Arizona citrus pests and the importance of the horticultural law. Ariz. Hort. Com. Circ. 2, 1 p.
Mentions citrus thrips.

(4) ——— ———.
1910. Report of the Entomologist of the Arizona Horticultural Commission for the year ending June 29, 1910. *In* Ariz. Hort. Com. 2d Ann. Rept., p. 8–15.
Page 11: Orange thrips.

(5) Jones, P. R. and Horton, J. R.
1911. The orange thrips. U. S. Dept. Agr. Bur. Ent. Bul. 99, pt. 1, p. 1–16, 2 fig., 3 pl.

(6) Morrill, A. W.
1911. Entomology. *In* Univ. Ariz. Agr. Exp. Sta. 22d Ann. Rpt., p. 551–556.
Pages 552–554: Note on thrips spraying.

(7) ——— ———.
1911a. Report of the Entomologist of the Arizona Horticultural Commission for the year ending June 28, 1911. *In* Arizona Hort. Com. 3rd Ann. Rpt., p. 10–33, 13 fig.
Page 24: Citrus fruit insects.

(8) Quayle, H. J.
1911. Citrus fruit insects. Cal. Agr. Exp. Sta. Bul. 214, p. 443–512, 74 fig.
Pages 490–493, figs. 48–51: Thrips.

(9) Morrill, A. W.
1912. The citrus thrips, with reference to other species affecting citrus. *In* Cal. State Com. Hort. Mo. Bul., v. 1, no. 5, p. 162–171, fig. 56–62.

(10) ——— ———.
1912. Report of the entomologist of the Arizona Horticultural Commission for the year ending June 30, 1912. *In* Ariz. Hort. Com. 4th Ann. Rpt., p. 15–43, fig. 2–12, 1 pl.
Page 32: Note on extent of injury in Arizona in 1912.

(11) Jones, P. R.
1912. Some new California and Georgia Thysanoptera. *In* U. S. Dept. Agr. Bur. Ent. Tech. Ser. 23, pt. 1, p. 1–24, 7 pl.
Pages 10–14: Euthrips.

(12) MORRILL, A. W.
1913. Report of the entomologist of the Arizona Commission of Agriculture and Horticulture for the year ending June 30, 1913. *In* Ariz. Hort. Com. 5th Ann. Rpt., p. 11–48, 11 fig.
Page 35: Citrus pests.

(13) ———.
1914. Report of the entomologist of the Arizona Commission of Agriculture and Horticulture. *In* Ariz. Hort. Com. 6th Ann. Rpt., p. 9–47, 11 fig.
Page 31: Note on injury in Arizona by citrus pests.

(14) HOOD, J. D.
1914. On the proper generic names for certain Thysanoptera of economic importance. *In* Proc. Ent. Soc. Wash., v. 16, no. 1, p. 34–44.
Page 40: *Scirtothrips citri.*

(15) HORTON, J. R.
1915. Control of the citrus thrips in California and Arizona. U. S. Dept. Agr. Farmers' Bul. 674, 15 p., 7 fig.

(16) MORRILL, A. W.
1915. Report of the entomologist of the Arizona Commission of Agriculture and Horticulture for the year ending June 30, 1915. *In* Ariz. Hort. Com. 7th Ann. Rpt., p. 9–50, 18 fig.
Page 35: Note on injury for 1915.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY

▽